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### ⑥ SCHEME FOR RAPID ADJUSTMENT OF NETWORK IMPEDANCE.

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**CH-A- 485 346**  
**FR-A- 2 137 013**  
**GB-A- 2 120 875**

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### Description

## FIELD OF THE INVENTION

5 The present invention relates to the control of transfer impedance in an alternating current system including particularly power transmission systems. More specifically, the present invention is directed to the use of a static controlled reactance connected in series within a transmission system to facilitate effective control of the power or current on the transmission line.

## 10 BACKGROUND OF THE INVENTION:

The power transmitted between two points in an AC electric power transmission system is primarily determined by the magnitude of the voltages at the two points, the angle between the vectors related to these two voltages, and the transfer impedance between the two points. Power is proportional to the voltage magnitudes. However, voltage magnitudes are generally controlled to within relatively small range of specified limits to stay within maximum design limits and to prevent unacceptable voltage variations in the supply voltages provided the utility customer. With large fixed transfer impedances, the degree of control of power by adjustment of voltage is limited. The power transmitted is approximately proportional to the sine of the angle between the two voltage vectors. It is therefore common to control the powerflow by adjusting the angle between the respective voltage vectors. The control of powerflow by controlling this angle between the voltage vectors is generally achieved by the relatively slow adjustment of rotor angles of synchronous machines. In such a case, the maximum permissible angle, and thus the power transmitted, may be limited by considerations of system transient and dynamic stability.

A variety of methods involving shunt reactive devices have been used to increase the power transfer capability and transient and dynamic stability limits. Synchronous condensers, shunt capacitors, shunt reactors, thyristor switched and/or controlled static VAR compensators and saturable reactor compensators are shunt devices used for the purpose. These methods are sometimes referred to as Surge Impedance Compensation or Compensation by Sectioning.

Series capacitor compensation is also sometimes utilized to improve stability limits and increase transfer capability by reducing transfer impedance. This method is sometimes referred to as line length compensation and is essentially a passive compensation technique. Series capacitors have, in a limited way, been switched in and out of the line to enhance stability performance. Otherwise, as a passive device, series capacitors cannot be used for smooth control of transmitted power. Since the transmitted power is inversely proportional to the transfer impedance, the effectiveness of series capacitor compensation to 35 reduce transfer impedance and raise power transfer limits increases with increasing levels of series capacitor compensation. For example, with other factors constant, 50 percent series capacitor compensation reduces transfer impedance to approximately half the original transfer impedance and doubles the maximum power in terms of steady state stability limits. An additional 25 percent compensation that would 40 reduce the transfer impedance to one-fourth the original value would increase the maximum power in terms of its steady state stability limit to four times the original value.

Despite this more than proportional increase in power transfer created by increasing levels of series capacitor compensation, high levels of series capacitor compensation have not heretofore been utilized. It is generally accepted that the practical upper limit of the degree of series compensation is of the order of 80 percent.

45 Document US-A-4 434 376 refers to means for damping sub-synchronous oscillations and DC offset in an A.C-power system. The damping apparatus described therein includes a reactance connected in series with a power line with selectively bi-directional conductors in parallel with the reactance whereby the reactance can be shorted. A damping resistor is inserted into the circuit when the particular problem condition is detected through thyristors.

50 Document FR-A 2 137 013 discloses an arrangement to adjust the transfer impedance by adding an  
adjustable in-series capacitive reactance. Thereby there are presented two approaches which both are  
characterized by the introduction of a capacitive compensation through a current transformer. This is  
reached in the first case by adjusting the transformer tap-changer position and in the second case by  
mechanically moving the armature of an inductor with air-gap connected in parallel to the capacitor at the  
55 secondary side of the current transformer. It is important to note that the technical teaching disclosed  
therein is directed to systems which much higher than normal power system frequency such as power  
supplies for aircrafts or for induction heaters (see introductory part). In practice it is unpractical to apply this  
type of arrangement in normal electric power transmission and distribution systems of 50 or 60 Hz and

systems of relatively high power. Moreover, the adjustment of the inductance is made through a mechanical rotary device, the operation of which is necessarily slow and therefore unsuitable for power transmission applications.

5 High levels of compensation close to 100 percent could produce (1) uncontrollable variations in power or current for small changes in terminal voltages or angles; (2) potentially damaging, undamped, subsynchronous oscillations; and (3) large transient currents and voltages during disturbances due to series resonant conditions.

These large transient currents or voltages may be overcome by the use of gapless metal-oxide varistor (MOV) arresters for overvoltage protection of the series capacitors. Limiting the overvoltage across the 10 series capacitors in such high transient current conditions to the clipping level of the MOV arrester has the effect of changing the effective capacitance value of the series capacitor during such a transient period. This temporarily detunes the series resonance circuit and prevents the transient current from reaching very high values.

The first and second problems mentioned above stem from the problem of lack of adequate controllability 15 of power on the AC transmission system. However, this problem is solved by the present invention.

In interconnected power systems, sometimes there is the problem of unscheduled powerflow through parts of the network due to mismatch between scheduled and actual powerflows. The present invention facilitates adjustment of the relative impedances of different parts of the transmission network to make the actual powerflow closer to the scheduled powerflow.

20 The present invention further facilitates adjustment of the transfer impedances of various parts of the transmission system to provide powerflow conditions while minimizing losses.

#### OBJECTS OF THE INVENTION

25 The device of the present invention is a series static controlled reactance to be inserted in an AC electric power transmission system for rapid continuous adjustment of the transfer impedance of the transmission system. The device may include fixed or switchable series capacitive or inductive reactance for operation with the continuously adjusted reactance to increase control sensitivity and/or control range. The device of the present invention could therefore be used to effectively control the power or current in the 30 transmission system to overcome potential problems of higher levels of series capacitor compensation as well as minimize unscheduled powerflow and losses in the transmission system.

It is therefore an object of the present invention to provide a new static means of power control where rapid fine control of the transfer impedance is facilitated through the use of series static controlled reactance;

35 It is another object of the present invention to provide a high degree of controllability of the power on an AC transmission line;

It is still another object of the present invention to provide such a high degree of controllability of power on an AC transmission line by the use of a series controlled reactance device of relatively small size which becomes a significant or dominant part of the transfer impedance;

40 It is a further object of the present invention to utilize the series static controlled reactance of the present invention to facilitate series capacitor compensation levels significantly higher than those presently utilized;

It is still a further object of the present invention to enhance transient and dynamic stability performance of such a transmission system utilizing the series static controlled reactance of the present invention along 45 with high levels of series compensation;

It is still a further object of the present invention to facilitate adjustment of the values of impedances of different parts of a transmission system to minimize unscheduled powerflow;

It is still a further object of the present invention to facilitate adjustment of the values of impedances of different parts of a transmission system to minimize losses.

50 These objects are accomplished by the static controlled reactance device inserted serially with the AC power transmission line as described in the present application.

#### SUMMARY OF THE INVENTION

55 The present invention is directed to an apparatus for network impedance adjustment in a transmission line wherein a controlled reactance is connected in series with the transmission line. The controlled reactance is constructed of a controlled inductor (reactor) connected in parallel to a fixed reactance. The controlled inductor is formed of an inductor connected in series with a static switch which controls the

conduction period of the inductor to vary the effective reactance of the inductor. Back-to-back connected thyristors could function as the serially connected static switch. Varying the conduction period of the inductor results in discontinuous current through the inductor. The parallel electrical circuit made up of fixed reactances is connected to the controlled inductor to filter harmonics due to the discontinuous current and to obtain the desired range of variable reactance. The controlled reactance device comprising the controlled inductor and parallel reactances may be connected in series with the transmission line directly or by connecting across the secondary winding of a transformer having its primary winding serially connected in the transmission line. Connection of the device on the secondary side of the transformer facilitates arrangement of the device in delta configuration in a three-phase system to eliminate triplen harmonics.

10 Further reduction in harmonics generated by the device is possible by splitting the device into two for connection to wye- and delta-connected secondary windings of the transformer with the primary winding serially connected to the transmission line.

The present invention overcomes the above mentioned first and second problems discussed in the Background of the Invention section of this application by introducing a static controlled series reactance to make the variable reactance a significant, if not dominant, part of the transfer impedance. By varying this controlled reactance, the transfer impedance can be modified sufficiently to effectively control the power or current on the transmission line. Use of this variable reactance along with high levels of series capacitor compensation, allows the device to be constructed of relatively small and economical size. For example, with 100 percent of the series inductive reactance part of the transfer impedance compensated by series 20 capacitors, the transfer impedance will be essentially very small corresponding to the series resistance. In this case, a static controlled series reactance device of small size, for example, 10 percent of the uncompensated transfer impedance, can provide control over a very wide range of power or current. By making the dominant transfer impedance controllable, the problem of uncontrollable power variations during small disturbances of high levels of fixed series capacitor compensation may be easily overcome. The 25 power or current of the system may easily be controlled within specified limits by fast continuous control of the transfer impedance. As power variation is sensitive to variations in the static controlled reactance, dynamic control of the device of the present invention facilitates the damping of any potential subsynchronous oscillations.

The size of the device necessary for rapid adjustment of impedance depends on the range and 30 sensitivity of the power control desired. The device of the present invention may be utilized with any level of series capacitor compensation and even without series capacitor compensation, for example, in the case of a short line. When operating at close to 100 percent series compensation with this device, the power on the line would be more sensitive to terminal voltage magnitudes making it possible to control the power by controlling the terminal voltages, for example, by a mechanical or solid state transformer tap changer, by 35 synchronous machine excitation control, or by a static VAR system. The device of the present invention may be operated to produce fast change of transfer impedance to improve transient stability or to modulate power or current through the transmission line to improve dynamic stability.

The problem of unscheduled powerflow due to mismatch between actual and scheduled powerflows in a transmission system is essentially a problem of controlling the relative impedances of different parts of 40 the network to match the required powerflow. The device of the present invention adjusts the impedance of different parts of the network to match the powerflow schedules and thereby minimize unscheduled powerflow.

As the device of the present invention adjusts impedances of different parts of the network, it could be used to adjust impedances in such a way as to minimize losses in the total system or parts of the system.

46 **BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which describe preferred embodiments of the present invention 50 only. In the drawings:

Figure 1(a) illustrates schematically the insertion of a device for rapid adjustment of network impedance directly in a transmission line;

Figure 1(b) schematically illustrates the insertion of a device for rapid adjustment of network impedance according to the teachings of the present invention into a transmission line through a transformer;

55 Figure 2 illustrates one general form of the device for rapid adjustment of network impedance according to the teachings of the present invention;

Figures 3(a) and 3(b) show additional forms of the device for rapid adjustment of network impedance according to the teachings of the present invention;

Figure 4(a) illustrates the connection of devices for rapid adjustment of network impedance according to the teachings of the present invention through a transformer in a three-phase AC transmission system for 6-pulse operation; and

5 Figure 4(b) illustrates the insertion of devices for rapid adjustment of network impedance formed according to the teachings of the present invention through a transformer in a three-phase AC transmission system for 12-pulse operation.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 Figures 1(a) and 1(b) illustrate two manners of interconnecting a device for rapid adjustment of network impedance formed according to the present invention and illustrated in Figures 2, 3(a) and 3(b), respectively, in one line of an AC power transmission system. Each of these figures could alternatively illustrate one line of a three-phase AC power transmission system, or a single phase AC electrical power circuit.

15 Referring to Figure 1(a), a transmitting end AC device 2 transmits power to a receiving end AC device 4 via transmission lines 6,8. In order to provide network impedance compensation and power control, a device for rapid adjustment of network impedance 10 formed according to the teachings of the present invention is serially provided in the transmission line.

20 Alternatively, as shown in Figure 1(b), wherein like elements are designated by like numbers, the transmitting end AC device 2 transmits power over transmission lines 6,8 to the receiving end AC device 4 in a manner identical to that of Figure 1(a). Similarly, a device for rapid adjustment of network impedance 10, formed according to the teachings of the present invention, is provided for interaction with the transmission line. However, in the Figure 1(b) embodiment, a series transformer 12 is provided having a primary coil 14 serially connected in the transmission lines 6,8 and a secondary coil 16 to which the device for rapid adjustment of network impedance 10 formed according to the teachings of the present invention is connected. This arrangement using series transformers requires the extra cost of the transformer but provides several benefits. Use of the transformer provides flexibility in the choice of voltage and current levels in the device for rapid adjustment of network impedance formed according to the teachings of the present invention, which, in the preferred embodiment utilizes back-to-back connected thyristors. Further advantages of the use of such transformers will be discussed later.

25 A preferred embodiment of the device for rapid adjustment of network impedance 10 of Figures 1(a), 1-b, is illustrated in Figure 2. An inductor X<sub>20</sub> is serially connected to a static switching device (generally indicated as 22) to form a controlled inductor 21. The static switching device is, in the preferred embodiment, a pair of back-to-back connected thyristors 24,26 having gates 24G, 26G, respectively. While in the preferred embodiment, a pair of thyristors 24,26 is utilized as a switching device, other suitable power 30 switching devices such as Gate-turn-off thyristors or saturable reactors could also be utilized in place of the thyristors utilized in the preferred embodiment of the present invention or a single triac could be utilized.

35 A supplemental reactance X<sub>p,28</sub> is provided in parallel with the controlled inductor 21. This supplemental reactance X<sub>p,28</sub> may have two functions. The discontinuous current through the controlled inductor 21 produces harmonics, the characteristic ones being the odd harmonics 3, 5, 7, 9, 11, 13, etc. These harmonics are filtered by harmonic filters within the supplemental reactance X<sub>p,28</sub> connected in parallel thereto. Depending on the harmonic performance required for the particular application, the harmonic filters could consist of tuned or broad-band filters. Additionally, a fixed or switchable capacitor or inductor may be used as all or part of the supplemental reactance X<sub>p,28</sub> to obtain the required range of variation of the impedance of the device 10. The supplemental reactance X<sub>p,28</sub> may be all or partly made up of an existing 40 reactance or reactance device present in the transmission line.

45 As an example, assume the reactance of the inductor X<sub>20</sub> has a value of 10 ohms at fundamental frequency and thus the controlled inductor 21 has a reactance which may be varied to any value of 10 ohms or above. When the supplemental reactance X<sub>p,28</sub> has an inductive reactance of 40 ohms at fundamental frequency, it is possible to obtain a range of variation of impedance across the device 10 of 50 from 8 ohms to 40 ohms inductive due to the parallel combination of 40 ohms with the 10 ohms and up developed by the controlled inductor 21.

55 The nature of this parallel supplemental reactance X<sub>p,28</sub> can be further understood by reference to Figures 3(a) and 3(b). In the embodiments of Figures 3(a) or 3(b), a fixed capacitor, 30 or a fixed inductor, 34 in parallel with harmonic filters 32 are shown as connected in parallel with the controlled inductor 21. At fundamental frequency, the harmonic filters, 32 would have capacitive reactance. The impedance of the parallel combination of harmonic filters, 32 and the fixed capacitor, 30 or fixed reactor, 34 may be capacitive or inductive. The total impedance across the device between points A and B in Figures 2 and 3 could be a capacitive reactance or inductive reactance depending on the relative values of the supplemental reactance

$X_p$ , 28 and the controlled inductor 21. If necessary, a fixed or switchable series capacitor, 36 as shown by dotted lines in embodiments of Figures 3(a) and 3(b) may be used with the basic device to raise series compensation levels as desired for transmission needs or in order to enhance the effective control of the variable reactance on transmitted power or current.

5 In order to limit the fault duty on the switching device, 22 and in particular the thyristors 24,26 of the preferred embodiment, the inductor  $X_{20}$  may be divided into two, and placed on both sides of the switching device, 22. When the resistance and valve voltage drops in the device are neglected and if it is assumed that the line current contains negligible harmonics, the voltage between the points A and B in Figures 2 and 3 would be equal to the product of the line current and the effective fundamental frequency 10 reactance  $X_{eff}$  of the device between points A and B. By controlling the firing angle of the thyristors 24,26, between 90° and 180° of this voltage, the conduction angle  $\sigma$  of the controlled reactance can be varied. This 15 control of the firing angle of the thyristors 24,26 by supplying control signals to their respective gates 24g,26g may be performed in any conventional manner as is well known in the art of power electronics. Due to the unique configuration of the device 10, it is feasible to vary the firing angle of thyristors by use of 20 the current signal from the line or from the parallel fixed reactance circuit as a reference control signal. The variation in the conduction angle of the controlled inductor in this manner has the effect of varying its inductive reactance. Specifically, the firing angle  $\alpha$  of the thyristors and the conduction angle  $\sigma$  of the thyristor-controlled reactor is related by the equation

$$20 \quad \sigma = 2\pi - 2\alpha \quad (1)$$

If at full conduction, the fundamental frequency reactance of controlled conductor 21 is  $X$ , the effective fundamental frequency reactance,  $X_v$  at any conduction angle is given by the equation

25

$$X_v = \frac{\pi X}{\sigma - \sin \sigma} \quad (2)$$

30 If  $X_p$  is the fundamental frequency reactance of the supplemental reactance 28 parallel to the thyristor controlled reactor, the effective fundamental frequency reactance  $X_{eff}$  of the device for rapid adjustment of network impedance is determined by the parallel combination of  $X_p$  and  $X_v$ , and is

35

$$X_{eff} = \frac{X_p \cdot X_v}{X_p + X_v} \quad (3)$$

40 Thus by varying the firing angle of the thyristors, the impedance of the device may be varied and controlled.

Unlike the thyristor-controlled reactors in conventional shunt static VAR systems, the voltage across the device is variable over a wide range with the thyristor firing angle and the line current. However, this voltage can be calculated from the formula  $X_{eff}$  given above and the line current. If the rms value of line current is  $I$ , the rms value of voltage across the device,  $V$  between points A and B, is

45

$$V = I \cdot X_{eff} \quad (4)$$

50 Knowing the voltage  $V$  and the firing angle of the thyristors, the harmonic currents generated by the discontinuous current in the controlled inductor 21 can be determined by known theory of thyristor-controlled reactors. The rms value of the  $n$ th characteristic harmonic component  $I_n$ , is:

55

$$I_n = V \frac{4}{X} \frac{1}{\pi} \left[ \frac{\sin(n+1)\alpha}{2(n+1)} + \frac{\sin(n-1)\alpha}{2(n-1)} - \cos \alpha \frac{\sin n\alpha}{n} \right] \quad (5)$$

The device for rapid adjustment of network impedance 10, as illustrated in Figures 3(a) or 3(b) could also be inserted in the secondary windings of the series transformer 12 of Figure 1(b), if desired. The use of

series transformer allows flexibility in the choice of voltage and current levels in the thyristor-controlled reactor circuit. Additionally, in a three-phase AC transmission system, the transformer would facilitate delta-connection of the impedance adjusting devices constructed according to the teachings of the present invention thereby reducing filter requirements for triplen harmonics (third, ninth, fifteenth, etc.).

5 Figure 4(a) illustrates a 6-pulse arrangement utilizing the devices for rapid adjustment of network impedance 10 in a transformer connected system. A delta arrangement (generally indicated as 40) of devices for rapid adjustment of network impedance 10 includes three devices for rapid adjustment of network impedance 10, D1-D3, arranged in a delta configuration. Each of the devices for rapid adjustment of network impedance is connected across a respective secondary coil or winding S1-S3 of a transformer  
 10 T1-T3. A corresponding primary coil or winding of each transformer T1-T3 is serially connected to a transmission line L1-L3 of a three-phase AC transmission system for transmitting AC power from a transmitting end AC device on one end of the transmission lines L1-L3 to a receiving end AC device on the other end thereof.

The 6-pulse arrangement shown in figure 4(a) has secondary coils of the transformer connected in a  
 15 delta configuration. An alternate 6-pulse arrangement connects the secondary windings of the transformers in Y (Wye) configuration with three devices for rapid adjustment of network impedance arranged in delta configuration and connected to the secondary windings of the transformer.

In the embodiment of Figure 4(b), a 12-pulse arrangement utilizing a delta/wye configuration is  
 20 illustrated. Like elements with Figure 4(a) are labelled with like numerals. In the embodiment of Figure 4(b), six impedance adjusting devices constructed according to the teachings of the present invention (D4-D6 and D7-D9) are utilized. The series transformers T1-T3 have two secondary coils (S1a-S3a, and S1b-S3b, respectively). The impedance adjusting devices D4-D6 are arranged in a delta configuration (generally indicated as 50) which is similar to that illustrated in Figure 4(a). This delta configuration is connected to the first set of secondary coils S1a-S3a connected in delta configuration in the same manner as transformer  
 25 secondary coils S1-S3 in 4(a).

Additionally, the impedance adjusting devices D7-D9 of the Figure 4(b) embodiment, are arranged in a  
 30 delta configuration (generally indicated as 60) and connected to the second set of secondary coils S1b-S3b of the series transformer connected in wye configuration. One terminal of each second secondary coil S1b-S3b is commonly connected to an interconnection line 62.

35 The 12-pulse arrangement illustrated in Figure 4(b) allows the minimization of harmonic filtering requirements by providing for cancellation of harmonics (fifth, seventh, seventeenth, nineteenth, etc.) which are not characteristic of 12-pulse operation.

The control of the thyristors 24,26 of the static switching device 22, of each of the devices for rapid  
 40 adjustment of network impedance 10 may be accomplished as would occur to one of ordinary skill in the art, and as is frequently done in the art in devices such as static VAR systems or HVDC Transmission Systems. Control of these devices would require measurement of appropriate system variables, determination of the firing angles of the thyristors to obtain required steady-state and transient characteristics, and the generation of firing pulses. However, such techniques would be well within the skill of one of ordinary skill in the art.

45 Each device for rapid adjustment of network impedance 10 or its component parts would be provided, according to the teachings of the present invention, with protection normally required for such devices in power systems such as arresters, forced firing of thyristors to prevent valve failure, and/or bypass switches or gaps, and appropriate grounding arrangements.

The invention has been developed and explained primarily with respect to electric power transmission  
 50 systems, but is obviously applicable to other high voltage and low voltage electrical power circuits and such uses are intended to be covered by the invention.

### Claims

55 1. An apparatus disposed in an A.C.line between first and second AC devices for impedance adjustment in the A.C.line, comprising reactance means (28, 30, 34) in series with the A.C.line, a controlled inductor means (21) being connected in series with the A.C.line and in parallel with the reactance means (28, 30, 34), wherein the controlled inductor means (21) includes a series connection of an inductor (20) with a switch means (22) adjustably controlling the conduction period of the current passing through the inductor (20) to vary the effective reactance of the inductor.

2. The apparatus of claim 1 comprising:

- a transformer having a primary coil and a secondary coil; said primary coil being serially connected in said A.C.line;
- the controlled inductor means and the reactance connected in parallel thereto being connected to the secondary coil of said transformer.

5

3. The apparatus of Claim 2 wherein the A.C.line is a three-phase transmission line having three conductors each of said conductors having such a transformer with its primary coil serially connected thereto, the controlled inductor means and the reactance connected in-parallel thereto being connected to the secondary coil of the respective transformer.

10

4. The apparatus of Claim 3 wherein said secondary coils and said controlled inductor means with the reactances connected in parallel thereto are connected together in a delta configuration.

15

5. The apparatus of Claim 3 wherein said secondary coils of the transformer are arranged in a Y (Wye) configuration; said controlled inductor devices and reactances connected in parallel thereto being arranged in a three-phase delta configuration and connected to said Y (Wye)-connected secondary coils.

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6. The apparatus of Claim 3 wherein each of said transformers includes first and second secondary coils, the first secondary coils of each of said transformers being connected together in three-phase delta configuration, the second secondary coils from each of said transformers being connected together in three-phase Y (Wye) configuration; each of said controlled inductor means and their associated reactances being connected in three-phase delta configuration, one of the delta configurations is connected to the delta-connected secondary coils and the other one of the delta configuration is connected to the Y-connected secondary coils of said transformers.

25

7. The apparatus of any one of claims 1 to 6 wherein said reactance includes harmonic filters to filter harmonics caused by discontinuous current in said controlled inductor device.

30

8. The apparatus of any one of claims 1 to 6 wherein said parallel reactance is of inductive nature.

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9. The apparatus of any one of claims 1 to 6 wherein said parallel reactance is of capacitive nature.

10. The apparatus of any one of claims 1 to 6 further comprising a capacitance connected in series with said controlled inductor device in said A.C.line to raise the series capacitor compensation level in said A.C.line.

40

11. The apparatus of Claim 10 wherein said capacitance is a switched capacitor.

12. The apparatus of any one of claims 1 to 6 wherein said switch means comprises:
  - two thyristors connected back-to-back and each having a control gate; and
  - means, connected to said control gates, for controlling the firing of said thyristors to hereby control the impedance of said apparatus.

45

13. The apparatus of any one of claims 1 to 6 wherein said inductor is formed of first and second inductor portions connected in series with said switch means with said switch means disposed in between to limit fault current through said switch means.

## Patentansprüche

50 1. Vorrichtung in einer Wechselstromleitung zwischen einer ersten und einer zweien Wechselstromeinrichtung zum Einstellen der Impedanz in der Wechselstromleitung, mit einer in Reihe mit der Wechselstromleitung geschalteter Reaktanz (28,30,34), einer mit der Wechselstromleitung in Reihe und mit der Reaktaneinrichtung (28,30,34) parallel geschalteten gesteuerten Induktionseinrichtung (21), wobei die gesteuerte Induktionseinrichtung (21) eine Reihenschaltung eines Induktors (20) mit einer Schalteinrichtung (22) aufweist, die die Übertragungsspannung des durch den Induktor (20) fließenden Stroms regulierbar steuert, um die effektive Reaktanz des Induktors zu variieren.

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2. Vorrichtung nach Anspruch 1 mit:
  - einem Transformator, der eine Primärspule und eine Sekundärspule aufweist; die Primärspule ist in Reihe mit der Wechselstromleitung verbunden;
  - die gesteuerte Induktionseinrichtung und die mit dieser parallel verbundene Reaktanz sind mit der Sekundärspule des Transformators verbunden.
3. Vorrichtung nach Anspruch 2, wobei die Wechselstromleitung eine Drei-Phasen-Übertragungsleitung mit drei Leitern ist, wobei jede der Leiter einen derartigen Transformator aufweist, dessen Primärspule in Reihe damit verbunden ist, wobei die gesteuerte Induktionseinrichtung und die damit parallel verbundene Reaktanz mit der Sekundärspule des jeweiligen Transformators verbunden sind.
4. Vorrichtung nach Anspruch 3, bei der die Sekundärspulen und die gesteuerte Induktionseinrichtung mit den damit parallel verbundenen Reaktanzen in einer Delta-Anordnung miteinander verbunden sind.
5. Vorrichtung nach Anspruch 3, bei der die Sekundärspulen des Transformators in einer Y- (Ypsilon)-Anordnung angeordnet sind, wobei die gesteuerten Induktionsvorrichtungen und die damit parallel verbundenen Reaktanzen in einer Dreiphasen-Delta-Anordnung angeordnet und mit den Y-(Ypsilon)-artig verbundenen Sekundärspulen verbunden sind.
6. Vorrichtung nach Anspruch 3, bei der jeder der Transformatoren erste und zweite Sekundärspulen aufweist, wobei die ersten Sekundärspulen jedes der Transformatoren in einer Dreiphasen-Delta-Anordnung miteinander verbunden sind und die zweiten Sekundärspulen jedes der Transformatoren in einer Dreiphasen-Y- (Ypsilon)-Anordnung miteinander verbunden sind; jede der gesteuerten Induktionsvorrichtungen und ihre zugeordneten Reaktanzen sind in einer Dreiphasen-Delta-Anordnung verbunden, wobei eine Delta-Anordnung mit den Delta-artig verbundenen Sekundärspulen und die andere Delta-Anordnung mit den Y-artig verbundenen Sekundärspulen der Transformatoren verbunden ist.
7. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die Reaktanz Oberwellenfilter aufweist, um durch unterbrochenen Strom in der gesteuerten Induktionseinrichtung verursachte Harmonische zu filtern.
8. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die parallele Reaktanz induktiver Art ist.
9. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die parallele Reaktanz kapazitiver Art ist.
10. Vorrichtung nach einem der Ansprüche 1 bis 6, die außerdem eine Kapazitanz aufweist, die in Reihe mit der gesteuerten Induktionseinrichtung in der Wechselstromleitung verbunden ist, um die Reihenkondensator-Kompensationsstufe in der Wechselstromleitung zu erhöhen.
11. Vorrichtung nach Anspruch 10, wobei die Kapazitanz ein geschalteter Kondensator ist.
12. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die Schalteinrichtung aufweist:
  - zwei Thyristoren, die an den Rückseiten miteinander verbunden sind, von denen jeder ein Steuer-Gate aufweist, und
  - eine Einrichtung, die mit den Steuer-Gates verbunden ist, zum Steuern des Zündens der Thyristoren, um dadurch die Impedanz des Vorrichtunges zu steuern.
13. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei der Induktor von ersten und zweiten Induktorkörpern gebildet ist, die mit der Schalteinrichtung in Reihe verbunden sind, wobei die Schalteinrichtung dazwischen angeordnet ist, um Fehlerstrom durch die Schalteinrichtung zu begrenzen.

Revendications

1. Un appareil disposé dans une ligne C.A. entre un premier et un deuxième dispositif C.A. pour l'ajustement de l'impédance dans la ligne C.A., comprenant des moyens de réactance (28,30,34) en série avec la ligne C.A., des moyens d'induction commandées (21) connectés en série à la ligne C.A. et en parallèle aux moyens de réactance (28,30,34), les moyens d'induction commandées (21) contenant une connection en série d'un inducteur (20) avec des moyens de commutation (22) ajustablement commandant la période de conduction du courant passant au travers l'inducteur (20)

pour varier la réactance effective de l'inducteur.

2. L'appareil de la revendication 1 comprenant:
  - un transformateur présentant une bobine primaire et une bobine secondaire; la bobine primaire étant connectée en série dans la ligne C.A.;
  - les moyens d'induction commandés et la réactance y connectée en parallèle étant connectés à la bobine secondaire du transformateur.
3. L'appareil de la revendication 2, dans lequel la ligne C.A. est une ligne à transmission triphasée présentant trois conducteurs, chacun des conducteurs présentant un tel transformateur avec sa bobine primaire y connectée en série,
  - les moyens d'induction commandés et la réactance y connectés en parallèle étant connectés à la bobine secondaire du transformateur respective.
4. L'appareil de la revendication 3, dans lequel les bobines secondaires et les moyens d'induction commandés avec les réactances y connectées en parallèle sont connectés en une configuration delta.
5. L'appareil de la revendication 3, dans lequel les bobines secondaires du transformateur sont disposées en une configuration Y (i grec); les dispositifs d'induction commandés et réactances y connectées en parallèle étant disposés en une configuration delta triphasée et connectés aux bobines secondaires connectées en Y (i grec).
6. L'appareil de la revendication 3, dans lequel chacun des transformateurs contient des bobines secondaires premières et deuxièmes, les premières bobines secondaires de chacun des transformateurs étant connectées en configuration delta triphasée, les deuxièmes bobines secondaires de chacun des transformateurs étant connectées en configuration Y (i grec) triphasée;
  - chacun des moyens d'induction commandés et leurs réactances associées étant connectés en configuration delta triphasée, une des configurations delta est connectée aux bobines secondaires connectées en delta, et l'autre des configurations delta est connectée aux bobines secondaires connectées en Y du transformateur.
7. L'appareil de l'une des revendications 1 à 6, dans lequel la réactance contient des filtres d'harmoniques pour filtrer des harmoniques causées par du courant interrompu dans le dispositif d'induction commandé.
8. L'appareil de l'une des revendications 1 à 6, dans lequel la réactance parallèle est de nature inductive.
9. L'appareil de l'une des revendications 1 à 6, dans lequel la réactance parallèle est de nature capacitive.
10. L'appareil de l'une des revendications 1 à 6, comprenant de plus une capacitance connectée en série au dispositif d'induction commandé dans la ligne C.A. pour augmenter le niveau de compensation de capacité de série dans la ligne C.A.
11. L'appareil de la revendication 10, dans lequel la capacitance est un capaciteur commuté.
12. L'appareil de l'une des revendications 1 à 6, dans lequel les moyens de commutation comprennent:
  - deux thyristors connectés aux arrières et chacun présentant une gâchette de commande; et
  - des moyens, connectés aux gâchettes de commande, pour commander l'allumage des thyristors pour ainsi commander l'impédance de l'appareil.
13. L'appareil de l'une des revendications 1 à 6, dans lequel l'inducteur est formé par des premières et deuxièmes portions d'induction connectées en série aux moyens de commutation, les moyens de commutation étant disposés entre les deux pour limiter le courant de défaut au travers les moyens de commutation.

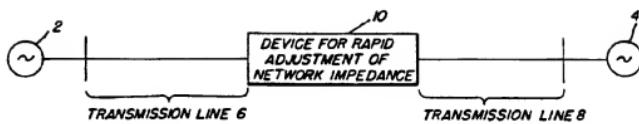


FIG. 1(a)

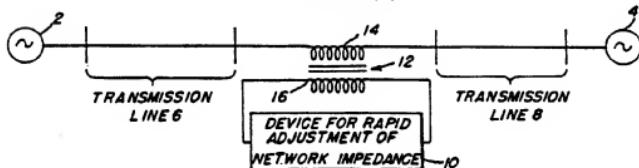


FIG. 1(b)

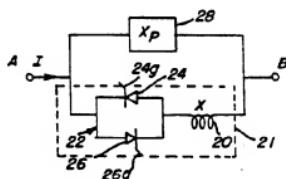


FIG. 2

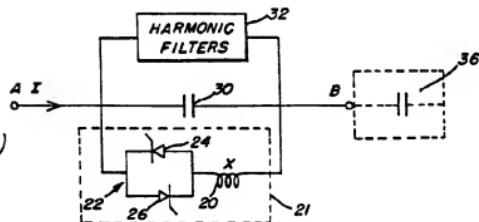


FIG. 3(a)

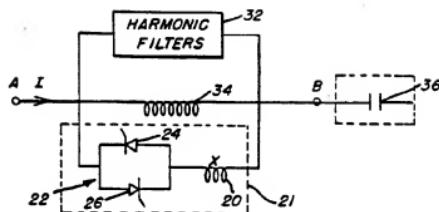


FIG. 3(b)

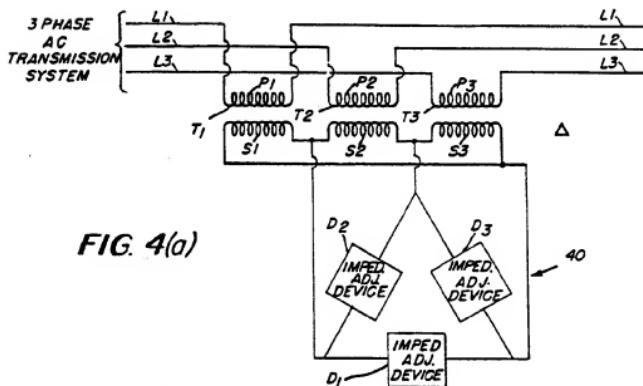


FIG. 4(a)

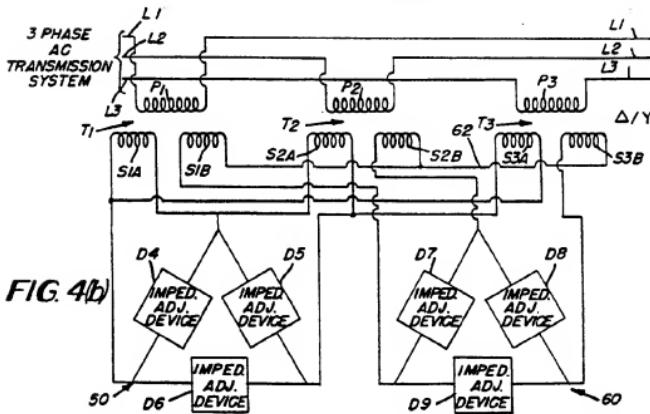


FIG. 4(b)